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INTERACTION OF PROCEDURAL FACTORS IN HUMAN PERFORMANCE ON YOKED SCHEDULES

CHRISTOPHER P. RAIA, STEPHEN W. SHILLINGFORD, HAROLD L. MILLER, JR., AND PHILLIP S. BAIER

BRIGHAM YOUNG UNIVERSITY

The differential effects of reinforcement contingencies and contextual variables on human performance were investigated in two experiments. In Experiment 1, adult human subjects operated a joystick in a video game in which the destruction of targets was arranged according to a yoked variable-ratio variable-interval schedule of reinforcement. Three variables were examined across 12 conditions: verbal instructions, shaping, and the use of a consummatory response following reinforcement (i.e., depositing a coin into a bank). Behavior was most responsive to the reinforcement contingencies when the consummatory response was available, responding was established by shaping, and subjects received minimal verbal instructions about their task. The responsiveness of variable-interval subjects' behavior varied more than that of variable-ratio subjects when these contextual factors were altered. Experiment 2 examined resistance to instructional control under the same yoked-schedules design. Conditions varied in terms of the validity of instructions. Performance on variable-ratio schedules was more resistant to instructional control than that on variable-interval schedules.

Key words: yoked schedules, instructional control, consummatory response, shaping, sensitivity, joystick, adult humans

The extension of operant conditioning from nonhuman to human subjects has uncovered several behavioral phenomena that have prompted further research. A puzzling but well-documented finding has been human subjects' rather marked insensitivity to contingencies of reinforcement in terms of the patterns of responding characteristic of nonhuman subjects. For instance, Lowe, Harzem, and Hughes (1978) compared the response patterns of humans working on fixed-interval (FI) schedules with those of pigeons working on similar schedules. Human subjects failed to display the scalloped or break-and-run responding that typified pigeons' performance. Weiner (1970) found that the performance of human subjects was not differentiated across FI and fixed-ratio (FR) schedules, whereas pigeons have responded differentially to variable-interval (VI) and variable-ratio (VR) schedules (a presumably more difficult task) when the schedules were equated for overall reinforcement value (Killeen, 1967; Zuriff, 1970).

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Requests for reprints should be sent to Christopher P. Raia, 128 Wellington Road, Garden City, New York 11530 (E-mail: cpraia@aol.com).

Streifel (1972) found that humans' response rates were equal on schedules of response-dependent and response-independent reinforcement. Conversely, Lattal (1974) found that pigeons responded more rapidly to increase the rate of response-dependent reinforcers and more slowly when reinforcement was response independent.

Pigeons' allocation of responses on concurrent VI schedules often matches the proportion of reinforcers obtained, which indicates a considerable sensitivity to reinforcement contingencies (Herrnstein, 1970). Yet, matching is often not displayed by humans in similar conditions (Schmitt, 1974).

Several studies have shown that human sensitivity to reinforcement contingencies can be manipulated experimentally by procedural variations, including the use of verbal instructions (see Lowe, 1979; Lowe, Beasty, & Bentall, 1983; Matthews, Shimoff, Catania, & Sagvolden, 1977). As Matthews et al. noted, variables that affect human sensitivity to contingencies may include the types of reinforcers used (e.g., food vs. money, credits, or points), the manner in which reinforcers are delivered (procedures that require high vs. low response cost), the amount of physical exertion required to perform various types of responses (a tedious, repetitious action vs. an interesting game), and the means by which initial responding is established (response shaping vs. verbal instructions or modeling).

Matthews et al. (1977) demonstrated experimental control of sensitivity to reinforcement contingencies by using human subjects and a yoked VR VI procedure. In this design, reinforcement availability on the VI schedule was determined by the occurrence of reinforcement on the VR schedule. This equalized the overall rates of reinforcement on each schedule while permitting subjects to respond differentially according to schedule type. Matthews et al. found that human subjects on VR schedules produced faster rates of responding than their counterparts working on VI schedules. Similar results have also been demonstrated using pigeons (Ferster & Skinner, 1957; Killeen, 1967; Zuriff, 1970). With human subjects, however, those different patterns of responding occurred only when three specific procedural criteria were satisfied: Verbal instructions to subjects were minimized, responding was established by shaping, and a consummatory response was performed following delivery of the reinforcer. One objective of the present study was to examine these variables more closely to ascertain their relative effects on response-rate differentiation. Of particular interest were the effects of verbal instructions on performance maintained by schedules of reinforcement—so-called instructional control (e.g., Baron & Galizio, 1983; Baron & Perone, 1982; Lowe, 1979).

Although the instructional control phenomenon has proven to be robust in experimental settings, it has yet to be thoroughly investigated. Ayllon and Azrin (1964) found that psychiatric patients who received reinforcers on an FR 1 schedule did not respond sufficiently to produce reinforcement without detailed instructions concerning the reinforcement contingency. Kaufman, Baron, and Kopp (1966) and Lippman and Meyer (1967) showed that instructions could exert strong control over responding. In some instances, they found that instructions trumped contingencies, that is, the latter had little discernible effect on subjects' behavior. In another study, subjects who were given correct instructions concerning contingencies were more likely to respond in a schedule-typical manner than were uninstructed subjects (Baron, Kaufman, & Stauber, 1969).

Buskist, Bennett, and Miller (1981) showed how instructions can affect the rate of responding of subjects on an FI schedule. Uninstructed subjects produced widely varying response rates, whereas subjects instructed to conserve session time produced high rates and subjects instructed to conserve responses produced intermediate rates.

Weiner (1970) demonstrated that instructions also can affect the extinction of operant behavior. In an experiment with young adults responding on an FR 10 schedule, uninstructed subjects showed a slow course of extinction. Subjects instructed concerning the maximum number of reinforcers to be received promptly ceased responding once the maximum was reached and no reinforcement followed.

Although many of these findings present a significant contrast to the typical behavior of nonhuman subjects, an intermediate effect has been observed when preverbal humans respond on reinforcement schedules. Several studies have shown that the operant behavior of infants is generally indistinguishable from that of animal subjects. However, by the age of 2 to 4 years, children (who have now acquired verbal skills) behave in a unique manner that is unlike either nonhuman or adult human subjects. When verbal abilities have been more fully developed by the age of 5 to 6 years and subjects can understand verbal instructions concerning contingencies, they behave akin to adults, displaying the characteristic insensitivity to actual contingencies and reliance on verbal instructions when the two are discrepant (Bentall & Lowe, 1987; Bentall, Lowe, & Beasty, 1983; Lowe et al., 1983).

The results of these experiments suggest that the presence of certain conditions, most notably the availability and content of verbal instructions, may constitute a form of stimulus control leading to patterns of responding that are not ordinarily associated with the schedule contingencies otherwise in place. Specifically, accurate instructions about schedule properties may lead to response patterns typical of nonhuman performance, and inaccurate instructions may produce patterns consistent with the instructions and deviant from the patterns otherwise exhibited. These results have led some writers to conclude that instructions can be more powerful in the control of human behavior than schedule contingencies per se (e.g., Brewer, 1974). Other theorists have pointed out that instructional control distinguishes human from nonhuman behavior and is a mark of human intelligence. Catania (1979) has stated, ''A major achievement of human verbal behavior is that it allows behavior to be controlled by descriptions of contingencies, in the verbal behavior of others, rather than by the contingencies themselves'' (p. 247).

In summary, the research cited here suggests that human operant behavior can be affected by schedules of reinforcement as well as by the manner in which responding is acquired, the presence or lack of a consummatory response, verbal instructions, or combinations of these factors. The present study further examined the relative contributions of the criteria identified by Matthews et al. (1977) as necessary for human sensitivity to reinforcement contingencies. Moreover, it probed the specific interaction between instructions and schedules of reinforcement by examining resistance to instructional control as a function of schedule type.

Experiment 1 investigated how contexts involving the provision of minimal verbal instructions (vs. detailed instructions or no instructions), the establishment of responding by shaping (vs. no shaping), and the performance of a consummatory response following reinforcement (vs. no consummatory response) affected subjects' sensitivities to reinforcement contingencies. First, baseline sessions were conducted with six 2-subject teams. In each team, 1 subject worked on a VR 30 schedule and the other worked simultaneously on a yoked VI schedule with all three variables (minimal verbal instructions, shaping, and a consummatory response) in place. In subsequent experimental conditions, 66 teams performed with none, one, or two of the variables in place in all possible permutations. The results of these experimental conditions were then examined to compare the differential contribution of each variable to subjects' performance.

Initially, we hypothesized that subjects' sensitivities to reinforcement contingencies would be affected more by verbal instructions than by the other variables due to the clear evidence of the potential of verbal instructions to strongly influence responding. We also expected that the effects of shaping and a consummatory response would be most evident in conditions in which verbal instructions were either minimized or absent, conditions that would presumably favor subjects' sensitivities to contingencies.

Experiment 2 specifically examined the relative resistance to instructional control of behavior sustained by VR and VI schedules. First, baseline rates of responding were established for two groups of 6 subjects in a condition using minimal instructions, shaping, and a consummatory response. Half of each group responded on a VR 30 schedule and the other half on a yoked VI schedule. The first group was initially presented with correct instructions concerning the contingencies, followed by incorrect instructions (intended to produce low response rates) in a subsequent session. The second group received the same instructions in the reverse order. Finally, differences between subjects' responding in the experimental conditions and the baseline condition were analyzed to determine the extent of instructional control on responding otherwise maintained by the schedule of reinforcement.

In Experiment 2, we predicted that the behavior of subjects on VR schedules would be more resistant to instructional control than that of subjects on VI schedules. Because a VR schedule typically produces faster and more extinction-resistant responding in pigeons than a VI schedule does when the two are equated for overall reinforcement rate (Killeen, 1967; Zuriff, 1970), we assumed that it would consequently play a more dominant role in the instruction–contingency interaction that was observed in subjects' behavior. For example, it seemed reasonable to expect that the behavior of subjects on VR schedules would be less affected by incorrect instructions concerning reinforcement contingencies than that of subjects on VI schedules.

EXPERIMENT 1

Method

Subjects. One hundred forty-four undergraduate students (age 18 to 22 years), solicited with the promise of financial compensation, served as subjects. The subjects were randomly divided into 12 groups of 12 subjects each, and each subject within a group was randomly assigned a partner. Each pair of subjects constituted a team. In each of the 72 teams, 1 subject responded on a VR schedule, and the other responded on a yoked VI schedule. The specific conditions under which each of the 12 groups of subjects performed varied by group.

Apparatus. Two private rooms (3 m by 2 m) were identically equipped with a table, chair, Apple II Plus® computer, color monitor, joystick, money dispenser, and coin bank. The computers were programmed in BASIC to provide a simple video game in which subjects could respond and receive reinforcers according to a preprogrammed schedule.

Each computer monitor displayed a moving target and a ''spaceship,'' which the subject could move in order to shoot at the target. The subject controlled the movements of the spaceship with a joystick. When a subject pressed the joystick button, the spaceship fired. Subjects received nickels from the money dispenser following a direct hit of the target. The vulnerability of the target to a direct hit was intermittent and software controlled.

Mechanical coin dispensers were salvaged from discarded vending machines and modified for control by the computers. Coin banks were constructed from large plastic cups (labeled ''bank'') equipped with covers that hid the coins from view after they were deposited. The use of the banks provided the consummatory response following reinforcement (i.e., subjects could be instructed to deposit coins in the banks). One bank always contained a few extra coins before the session began so that the session winnings by the 2 subjects would not be identical. In experimental conditions that did not include the consummatory response, the banks were removed from the rooms.

The computers were connected through a custom-built interface to a Digital PDP-11/4S® computer (programmed in SuperSKED®), which controlled the reinforcement contingencies and recorded subjects' response and reinforcement data. One computer (Computer A) always provided a VR 30 schedule (except during shaping phases), and the other computer (Computer B) provided a yoked VI schedule. Whenever Computer A delivered a reinforcer according to the VR 30 schedule, Computer B stored a reinforcer to be delivered following the next direct hit of the target. In this manner, the programmed contingencies provided different schedule types but offered equal rates of reinforcement.

Procedure. The various experimental conditions contained combinations of three variables of interest: presence or absence of a consummatory response, presence or absence of shaping, and instructions that were defined as rich (detailed), lean (minimal), or none (absent). The dependent variables were the cumulative numbers of responses (joystick button presses) produced by VR and yoked VI subjects, respectively, during the session.

Each team participated in a single session either 40 or 46 min in length. Teams in conditions in which responding was established by shaping experienced a 6-min primary shaping period in which each subject was exposed to an FR 1 schedule for 2 min, a VR 2 schedule for 2 min, and a VR 4 schedule for 2 min. Next, the subjects began a 40-min session in which the subject on Computer A worked on a VR 30 schedule and the subject on Computer B worked on a yoked VI schedule. Teams in conditions without a shaping phase participated only in the 40-min session. Each of these sessions was divided into 30-s intervals, and the numbers of responses and reinforcers delivered during each interval were recorded for each subject.

Following arrival at the research laboratory, each subject was individually escorted by an experimenter into a separate research room (one of the two private rooms), which was configured to minimize distractions and prevent interaction with the other member of the team. The two subjects were not identified to each other as constituting a team, nor were they informed that the actions of one (the VR subject) would influence the conditions of the other. The research rooms were equipped with one-way mirrors through which the experimenters could observe the subjects.

Each of the 12 conditions was assigned a three-letter designation specific to the consummatory response, shaping, and the type of instruction. The first letter notes the presence or absence of a consummatory response (C = presence, C′ = absence), the second the presence or absence of shaping (S = presence, S′ = absence), and the third the type of instructions given (R = rich, L = lean, N = none). For example, Condition CSR denotes a condition in which subjects performed a consummatory response, participated in the shaping phase, and were given rich instructions about their task. By contrast, Condition CS′L is the designation for a condition in which subjects performed a consummatory response, did not participate in the shaping phase, and received lean instructions about their task.

In conditions with lean instructions, subjects were shown a card (attached to the top of the table) and were asked to read the text on the card aloud. The instructions were as follows:

> Please read carefully:
> Do not ask for additional information about what you are to do. Your task is to win as much money as possible. You will receive nickels from the money dispenser. At the end of session, you may keep all of the money you win. Good luck.

In the conditions with rich instructions, subjects were shown a card containing the following:

> Please read carefully:
> Do not ask for additional information about what you are to do. Your task is to win as much money as possible. Use the joystick to move your spaceship and press the joystick button to fire at the enemy spaceship. The enemy spaceship has an invisible shield which is active only at certain times. To destroy the enemy spaceship, you must hit it in the center when the invisible shield is down. You will receive nickels from the money dispenser. The session will last about 40 minutes. Good luck.

In conditions in which the consummatory response was in effect, the sentence "When a nickel falls from the dispenser, remove it and place it in the bank" appeared immediately following the sentence "You will receive nickels from the money dispenser" in both sets of instructions.

Conditions with no instructions did involve some nonverbal modeling. Specifically, subjects sat in front of the computer while an experimenter, without saying anything, moved the spaceship vertically and horizontally with the joystick. The experimenter then fired a single shot at the target and registered a direct hit, which resulted in the delivery of a nickel. The experimenter also demonstrated the consummatory response—lifting the nickel from the money dispenser and inserting it in the bank—if applicable for the condition. Once the experimenter completed this demonstration, he spoke the following instructions and left the room: "Please wait here. I will tell you when to begin. Good luck."

At the end of each session, all subjects were interviewed and asked about the response strategies they had used. They were also informed of the purposes of the study once it had been completed.

Results

A cumulative response graph was produced for each subject. The graphs were created by plotting the cumulative number of responses in successive 30-s intervals across the 40-min session. Cumulative response graphs for the 2 subjects in each team were plotted on the same set of axes, allowing convenient comparison of the VR and yoked VI performances. The cumulative response profiles for all 72 teams in the 12 conditions are presented in Figures 1 through 6. In eight of the conditions—CSL (Figure 1), CSR (Figure 2), C′SL (Figure 3), C′SR (Figure 4), C′S′R (Figure 4), CSN (Figure 5), C′SN (Figure 5), and C′S′N (Figure 6)—the 6 VR subjects produced response rates that were similar to each other (i.e., within ±15% of the group mean). The VR subjects in the remaining conditions—CS′L (Figure 1), CS′R (Figure 2), C′S′L (Figure 3), and CS′N (Figure 6)—exhibited larger disparities in response rate, ranging from −58% to +32% of the group mean for Condition CS′L, −40% to +30% for CS′R, −19% to +21% for C′S′L, and −24% to +35% for CS′N.

In contrast, VI subjects displayed greater variability than VR subjects in response rates within conditions. An exception was Condition C′S′R (Figure 4) in which all 6 VI subjects closely approximated the response rates of their yoked VR counterparts. Condition CSL produced relatively low response rates (a mean of approximately 48 responses per minute; see Figure 1), whereas VI subjects in Condition CSN responded at rates that approximated those of VR subjects (a mean of about 93 responses per minute; see Figure 5). In the other conditions, on average, the re-

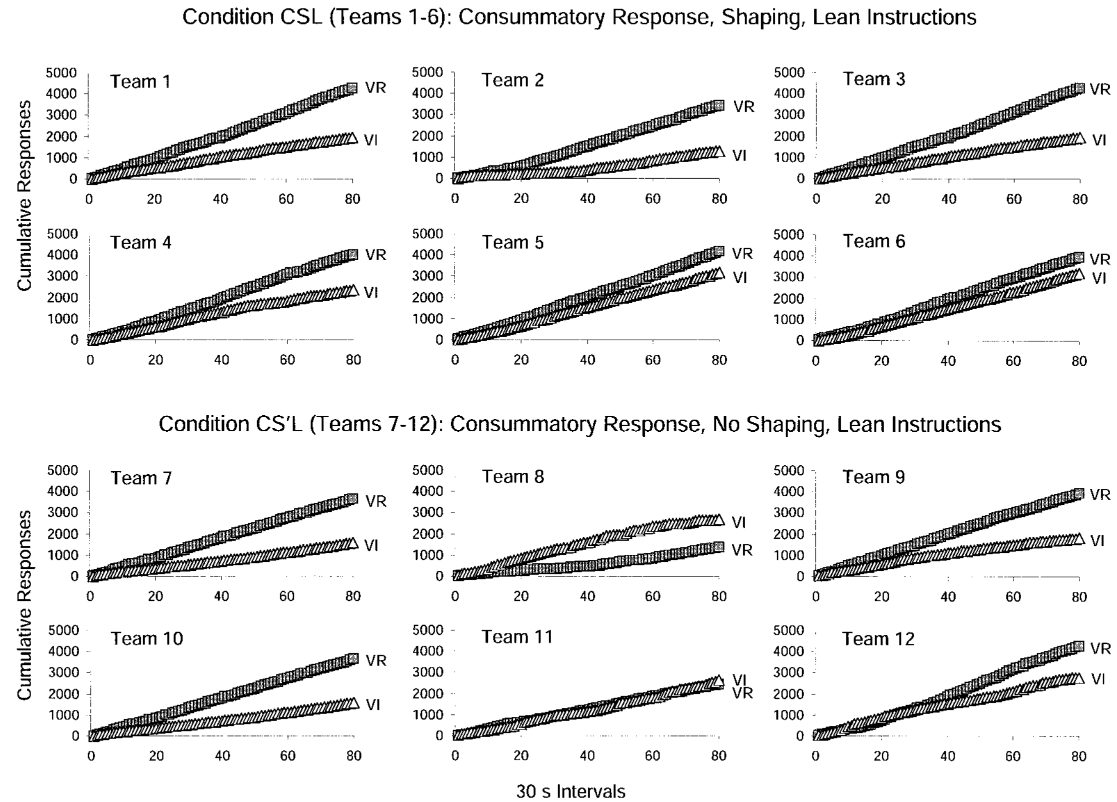

Fig. 1. Cumulative response graphs of teams in Conditions CSL (consummatory response, shaping, and lean instructions) and CS′L (no consummatory response, shaping, and lean instructions). Graphs show cumulative numbers of joystick responses of VR (shaded squares) and yoked VI (open triangles) subjects in successive 30-s intervals across a 40-min session.

sponse rates of VI subjects ranged between 52 and 82 responses per minute.

Three-factor (consummatory response, shaping, and instruction type) analyses of variance (ANOVA) were conducted for VR and yoked VI subjects separately to further clarify the relative effects of the independent variables on mean cumulative responses. The results revealed no significant effects for VR subjects. However, ANOVA revealed that there was a two-way interaction between instruction type and consummatory response for VI subjects, $F(2, 71) = 4.53$, $p < .05$, which is depicted in Figure 7.

In conditions in which no consummatory response was used, there was little difference in total cumulative responses among the three instruction conditions. Subjects under the VI schedule who received rich instructions displayed slightly higher response rates, averaging approximately 250 more responses by the end of the 40-min session than the other subjects. In conditions in which a consummatory response was used, the mean cumulative responses by VI subjects who received no instructions increased by about 800, whereas those by subjects in the lean instructions condition decreased by about 600. Responding by subjects in the rich instructions condition decreased slightly when the consummatory response was available. In other words, the addition of a consummatory response differentiated the three instruction conditions when VI schedules were used.

The differences in response rates between VR and yoked VI subjects both within and across conditions can be observed in Figures 1 through 6. In two conditions, CSL and C′S′R (Figures 1 and 4), the response rates of the six teams were highly consistent. The response rates of teams in the remaining 10 conditions lacked the same degree of consis-

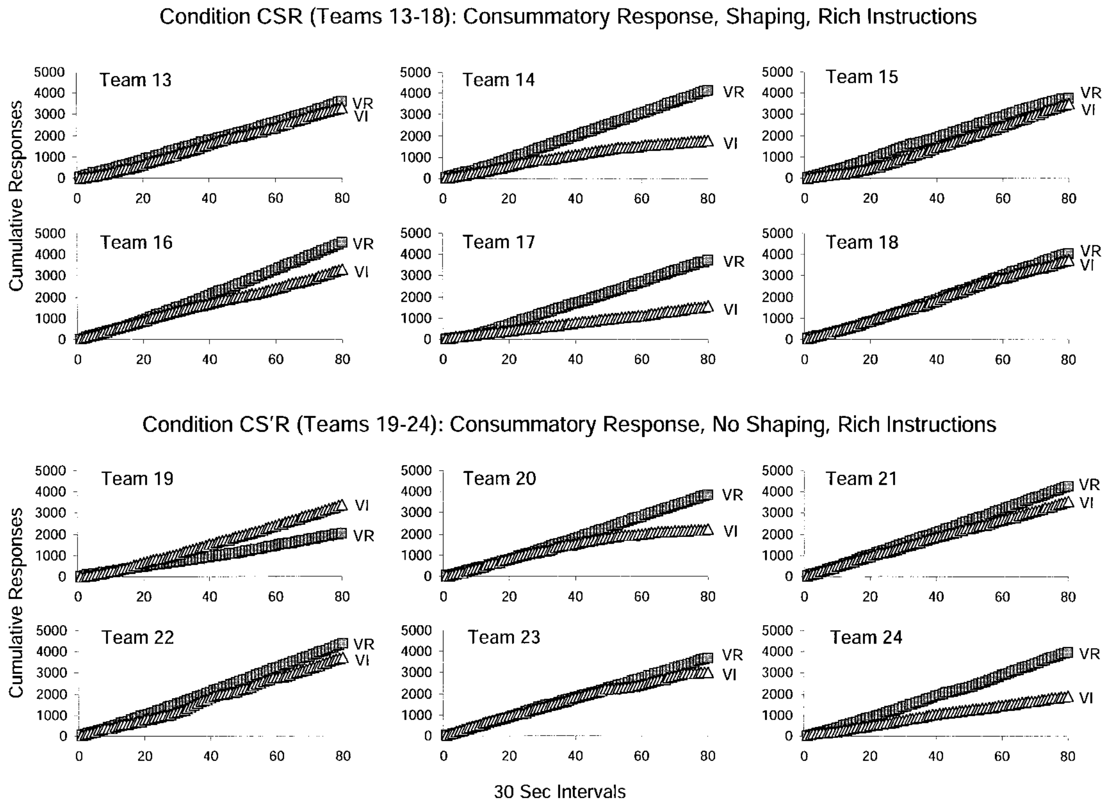

Fig. 2. Cumulative response graphs of teams in Conditions CSR (consummatory response, shaping, and rich instructions) and CS′R (consummatory response, no shaping, and rich instructions). Other details as in Figure 1.

tency. In Conditions CSR (Figure 2) and C′S′N (Figure 6), all VR subjects responded at higher rates than the yoked VI subjects, but the size of the difference varied by team from small to substantial. The teams in Conditions CS′L (Figure 1), CS′R (Figure 2), and C′SL (Figure 3) exhibited clear response-rate differences between VR and yoked VI subjects. In four teams across these three conditions, however, the response rate of the yoked VI subject was higher than that of the VR. Teams in Conditions C′S′L (Figure 3), C′SR (Figure 4), and CS′N (Figure 6) all showed large differences in response rate between VR and yoked VI subjects, but, for approximately half the teams across these conditions, the yoked VI subject responded at a faster rate than the VR subject. This effect also occurred among teams in the remaining conditions, CSN and C′SN (Figure 5). The differences in response rates between subjects, however, were somewhat smaller than those for subjects in Conditions CS′R, C′S′L, and C′SR.

For comparative purposes, Figure 8 presents histograms that summarize the differences in total responses between the VR and yoked VI subjects for each of the six teams in the 12 conditions. For example, the first histogram shows a difference of about 2,300 cumulative responses for Team 1 in Condition CSL. In other words, the VR subject in this team made about 2,300 more responses than did the yoked VI subject by the end of the 40-min session. The difference of about −600 cumulative responses for Team 38 in Condition C′SR represents the opposite case in which the VR subject made about 600 fewer responses than the VI subject.

Selected combinations of histograms permit comparison of differences in cumulative responses between VR and yoked VI subjects across conditions that differed by only one variable, allowing an appraisal of the effects of that variable. For example, comparing the histograms for teams in Conditions CSL and CS′L (as well as those in CSR and CS′R and

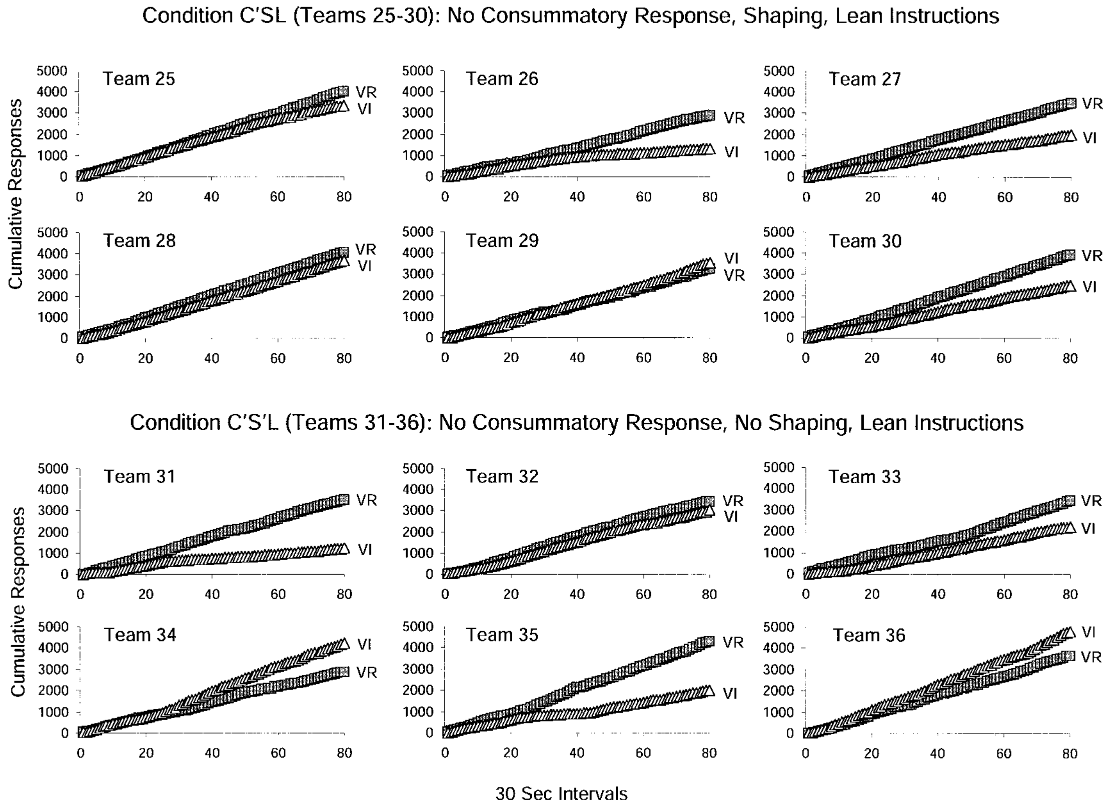

Fig. 3. Cumulative response graphs of teams in Conditions C′SL (no consummatory response, shaping, and lean instructions) and C′S′L (no consummatory response, no shaping, and lean instructions). Other details as in Figure 1.

in CSN and CS′N) conveys the differential produced by the presence or absence of shaping. In another comparison, the histograms for Condition C′S′R show that teams that experienced no consummatory response, no shaping, and rich instructions displayed consistently smaller differences in cumulative responses between VR and yoked VI subjects than teams that experienced no shaping, no consummatory response, and no instructions (Condition C′S′N).

The differences between VR and yoked VI responding can be described qualitatively in several ways. For example, it is possible to consider the performances within each condition in terms of consistency (i.e., the similarity of response profiles across the teams), direction (whether the difference between the total responses by the VR subject was greater than or less than the total by the yoked VI subject), or magnitude (the size of the difference in total responses). By these descriptors, the teams in Conditions CSL, CSR, C′SL, and C′S′N had positive direction. With the exception of only one team in these conditions (Team 29), VR subjects responded more, often much more, than their yoked VI partners. The teams in Condition CSL also showed high consistency and a generally large magnitude.

Discussion

A basic assumption is that when VR and VI schedules are equated for reinforcement rate, response rates maintained by the VR schedule tend to be greater than those for the VI schedule. As reported earlier, this difference consistently appears in research with nonhuman subjects but is not so clear when human subjects are involved. In the present study, the number of responses by the VR subject exceeded that of the yoked VI subject in 53 of the 72 teams. In 38 of these 53 teams, the VR subject exceeded the yoked VI subject by at least 250 responses. Thus, in general,

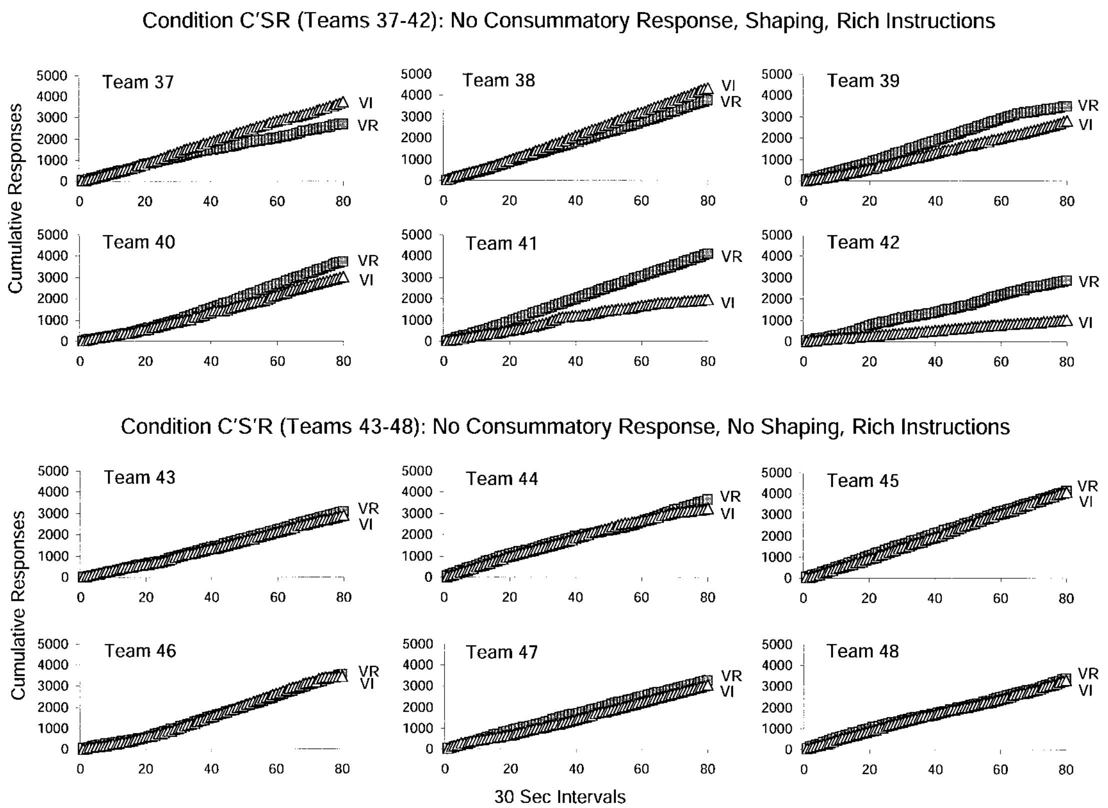

Fig. 4. Cumulative response graphs of teams in Conditions C′SR (no consummatory response, shaping, and rich instructions) and C′S′R (no consummatory response, no shaping, and rich instructions). Other details as in Figure 1.

the results were consistent with the typical outcome for nonhuman subjects.

By comparing the performance of teams in conditions that differed on only one variable, it is possible to estimate the effects of the variables in qualitative terms. Changes in one variable led to changes in one or more of the descriptors invoked earlier. For example, when shaping was present or absent in the conditions in which the consummatory response was used and lean instructions were in effect (Conditions CSL and CS′L), there was a moderate change in consistency and direction but only a small change in magnitude. The presence or absence of the consummatory response when shaping was absent and no instructions were given (Conditions CS′N and C′S′N) resulted in sizable changes in consistency and direction but almost no change in magnitude.

The analysis of the results in these terms can be extended to all 12 conditions by first asking about the differences in responding that existed when the presence of the consummatory response and the inclusion of shaping were held constant and only the type of instruction varied. Conditions CSR, CSL, and CSN provided this arrangement. The teams in Condition CSR all showed differences that were consistently in the positive direction, while magnitudes were mixed. In Condition CSL, positive direction characterized each team, as did high magnitude. For Condition CSN, however, magnitudes were low and the direction of differences was generally negative. Something about the absence of instruction, in which the only indicators of what the task involved were provided by the silent experimenter, produced a very different outcome.

In what might be considered the most primitive conditions (C′S′R, C′S′L, and C′S′N), the results were strikingly different. Now the teams that received rich instructions showed mixed direction and very low magnitude. By contrast, teams in Condition C′S′L

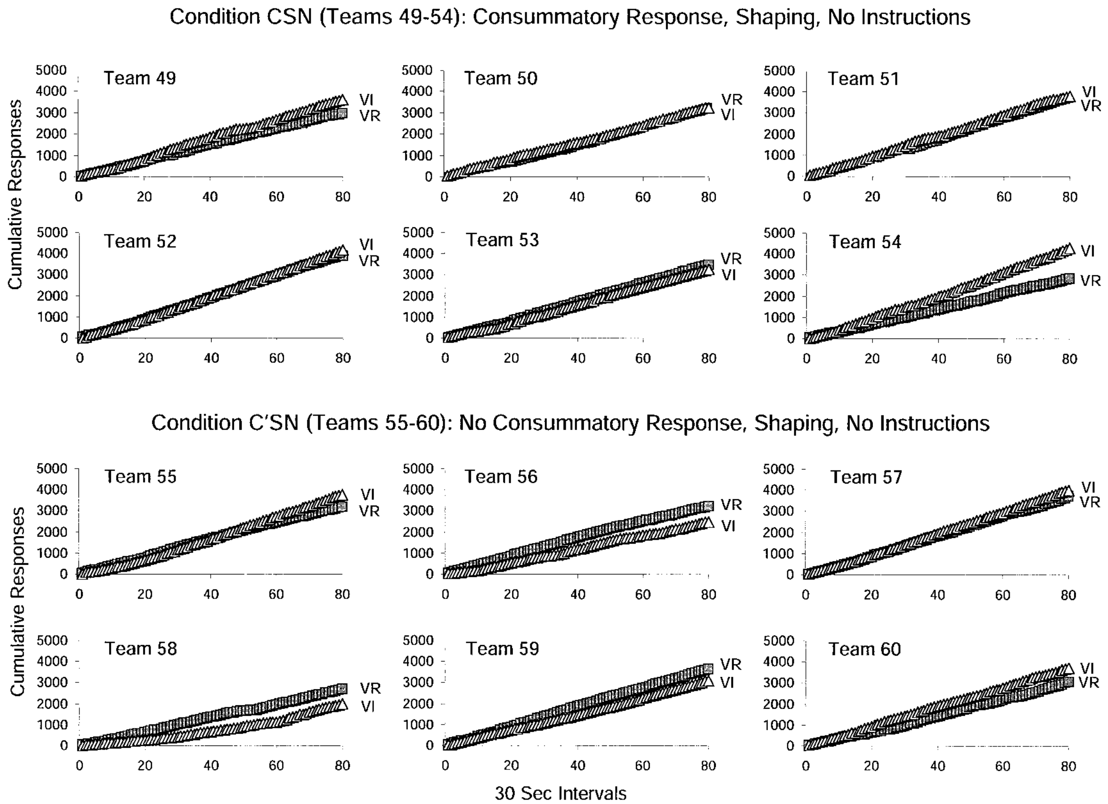

Fig. 5. Cumulative response graphs of teams in Conditions CSN (consummatory response, shaping, and no instructions) and C′SN (no consummatory response, shaping, and no instructions). Other details as in Figure 1.

showed mixed direction but generally high magnitude. Those in Condition C′S′N were uniform in positive direction and tended to high magnitude.

Although these results implicate all three independent variables—the consummatory response, shaping, and the type of instruction—in the control of performance, within each set of comparisons performance varied specifically with instruction. The same approach can be applied to the other two sets of comparisons in which instruction type varied while the presence or absence of the consummatory response and shaping was held constant. In Conditions C′SR, C′SL, and C′SN, the consummatory response was absent but shaping was present. The opposite occurred in Conditions CS′R, CS′L, and CS′N, in which the consummatory response was present and shaping was absent. However, despite these differences, the results were similar between the two sets of conditions. In general, the teams that received either rich or lean instructions exhibited mostly positive direction and moderate to high magnitude. Those that received no instructions showed mixed direction and low to moderate magnitude.

One interpretation of these results is that, by themselves, the presence or absence of the consummatory response and the presence or absence of shaping tended to exert similar effects within each category of instruction type. It was only their joint occurrence or nonoccurrence—both being present or both being absent simultaneously—that seemed to result in the differential outcomes of instruction type. Responding that followed rich instructions was very different when the consummatory response and shaping were both present or both absent (Conditions CSR and C′S′R, respectively). Marked differences likewise appeared between the conditions in which no instructions were given and both the consummatory response and shaping were included (CSN) or both were not

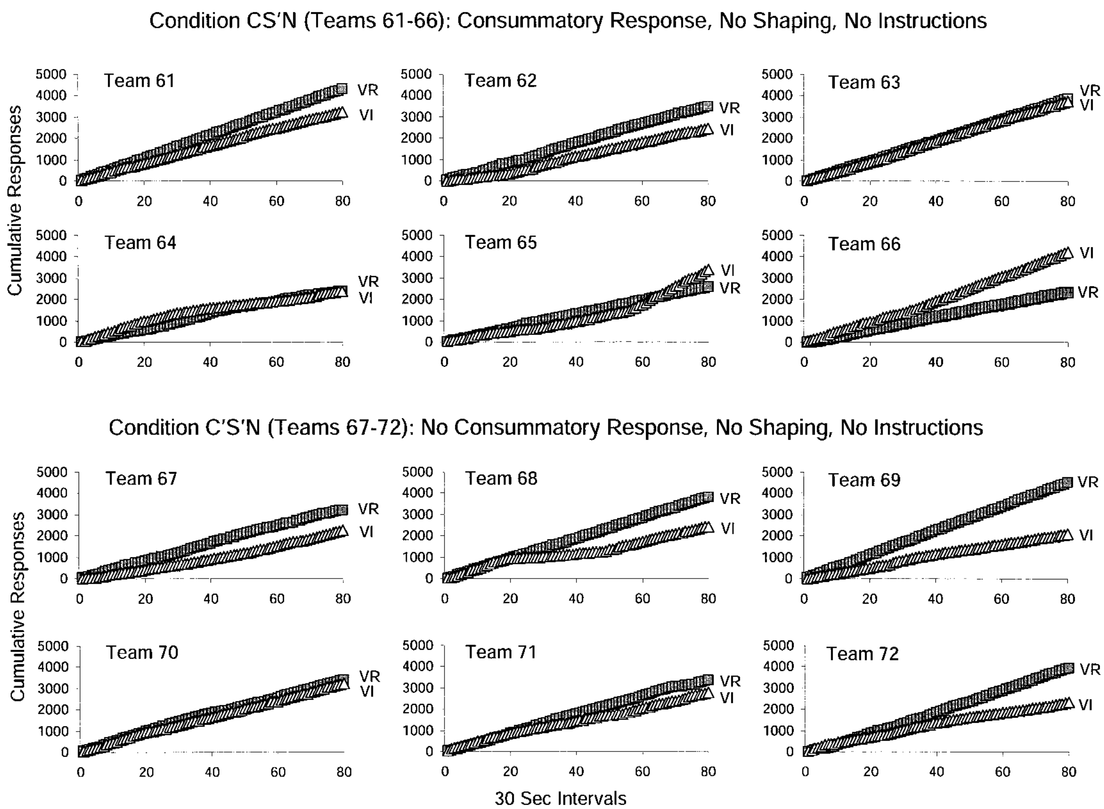

Fig. 6. Cumulative response graphs of teams in Conditions CS′N (consummatory response, no shaping, and no instructions) and C′S′N (no consummatory response, no shaping, and no instructions). Other details as in Figure 1.

(C′S′N). The differences were less extreme for the pair of conditions involving lean instructions (CSL and C′S′L).

The results affirm the previous finding (Matthews et al., 1977) that human subjects respond faster on VR schedules than their counterparts on yoked VI schedules when in-

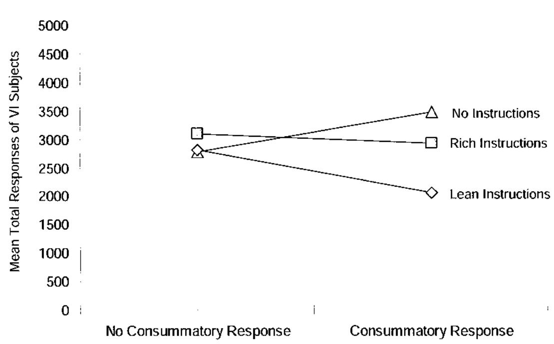

Fig. 7. Interaction between instruction type and availability of the consummatory response for the mean cumulative responses of VI subjects in Experiment 1.

structions are minimized (but still given), responding is established by shaping, and a consummatory response is performed following reinforcement (see Condition CSL). In addition, the results demonstrate that the size of the response-rate differences between team members was affected, sometimes dramatically, by specific combinations of the procedural variables.

Although it is difficult to determine exactly how each variable affected the response rates of VR and VI subjects (and consequently the response-rate differences between yoked team members), three conclusions can be drawn. The first is that the inclusion of a consummatory response, shaping, and lean instructions created a context that was optimal for the consistent appearance of a large difference between VR and yoked VI subjects' response rates. Under these conditions, VR subjects responded at approximately twice the rate of yoked VI subjects. This is consistent with the sensitivity to differential contin-

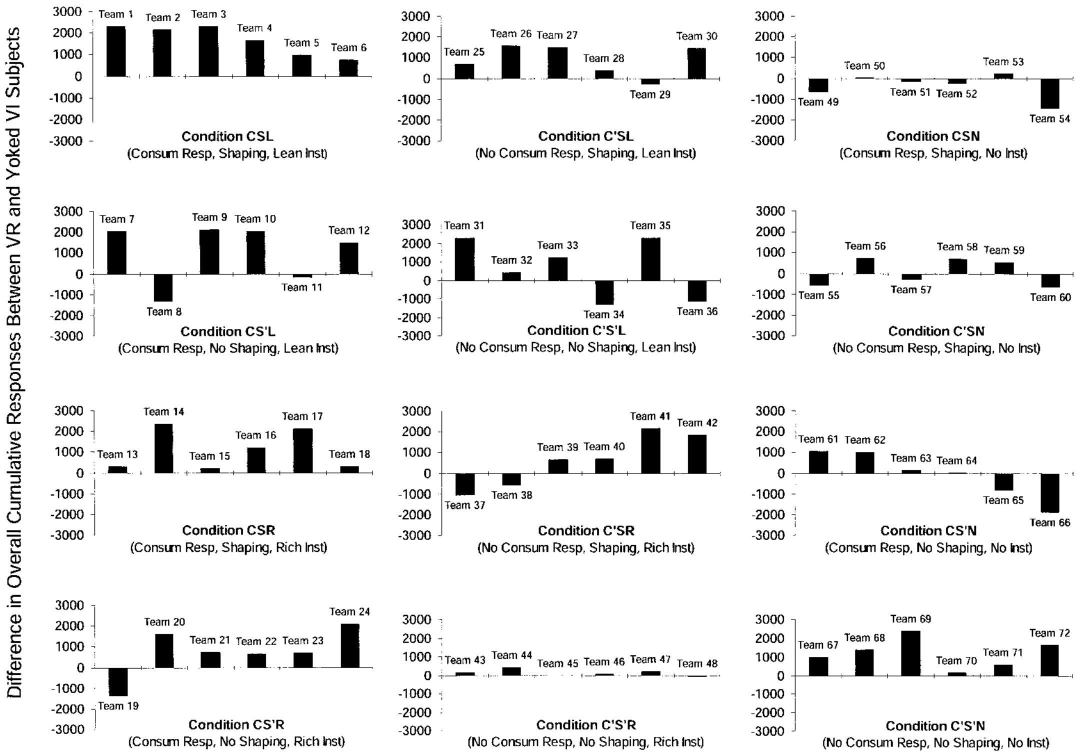

Fig. 8. Differences in cumulative responses between VR and yoked VI subjects for the 72 teams shown in Figures 1 through 6. Bars above the line indicate that the VR subject of the team produced more responses during the session than did the yoked VI subject. Bars below the line indicate the opposite.

gencies of reinforcement that is typically displayed by nonhuman subjects on yoked VR VI schedules. When this context was altered in other conditions, subjects varied in terms of their sensitivity to reinforcement contingencies.

The second conclusion is that, for the most part, the response rates of VI subjects were more vulnerable to alterations of the procedural variables included in this study than did those of VR subjects. In most conditions, the response rates of VR subjects tended to be similar. By comparison, the response rates of VI subjects varied widely. In the majority of cases in which response-rate differences appeared between VR and yoked VI subjects within a condition, these differences were due to the variance in VI subjects' response rates.

Finally, the variable that appeared to have the greatest influence on VI subjects' response rates was instruction type; however, the specific effect of instruction type was moderated by the joint presence or absence of a consummatory response and shaping. Exactly why VI subjects' response rates were differentially affected by instructions only when both were present is a matter of speculation, requiring additional research. It seems clear, however, that the joint inclusion of the consummatory response and shaping, coupled with lean instructions, were the factors that were most effective in promoting VI subjects' sensitivity to the schedule of reinforcement.

EXPERIMENT 2

In this study, two of the variables studied in Experiment 1 (shaping and the inclusion of a consummatory response) were present and held constant. Instructional type was varied between minimal, correct, and incorrect. The correct and incorrect instructions were also defined as rich in the same sense as those used in Experiment 1.

Method

Subjects. Twelve male undergraduate students, solicited with the promise of financial compensation, served as subjects. They were randomly divided into two groups (Groups 1 and 2) of 6 subjects each. Each group was further subdivided into two subgroups of 3 subjects each (Subgroups 1a, 1b, 2a, and 2b). Each subject in Subgroup 1a was randomly paired with a subject in Subgroup 1b, and each subject in Subgroup 2a was randomly paired with a subject in Subgroup 2b, creating a total of six 2-member subject teams (Teams 1 through 6). Subjects in Subgroups 1a and 2a were assigned to a VR 30 schedule, and subjects in Subgroups 1b and 2b were exposed to a yoked VI schedule.

Apparatus. The apparatus used in Experiment 2 was identical to that in Experiment 1.

Procedure. Subjects participated in teams of 2, 1 subject working on Computer A and the other on Computer B. Each team participated in one 46-min baseline session and two 40-min experimental sessions. In each session, the numbers of responses and reinforcers delivered in each 30-s interval were recorded.

Following arrival at the research laboratory, each subject was escorted into a research room by an experimenter. The experimenter asked each subject to read aloud a set of instructions written on a card that was taped to the table. After each subject had read the instructions aloud, the experimenter left the room. The instructions were as follows:

> Please read carefully:
> Do not ask for additional information about what you are to do. Your task is to win as much money as possible. You will receive nickels from the money dispenser. When a nickel falls from the dispenser, remove it and place it in the bank. At the end of the session, you may keep all of the money in the bank. The session will last about 40 minutes. Good luck.

In Session 1, all subjects received a 6-min primary shaping phase in which they were exposed to an FR 1 schedule for 2 min, a VR 2 schedule for 2 min, and a VR 4 schedule for 2 min. Following this phase, the subjects began a secondary shaping and baseline response phase. Computer A provided a VR 10 schedule for 4 min, a VR 20 schedule for 4 min, and a VR 30 schedule for the remaining 32 min of the session. Computer B always provided a VI schedule yoked to the VR schedule.

Table 1

Assignment of additional instructions in Experiment 2. See text for the actual instructions.

Subgroup	Session	Instruction paragraphs	Instruction type
1a (VR subject)	2	(i) and (iii)	Correct
1b (VI subject)	2	(i) and (iv)	Correct
1a (VR subject)	3	(ii) and (v)	Incorrect
1b (VI subject)	3	(ii) and (v)	Incorrect
2a (VR subject)	2	(i) and (v)	Incorrect
2b (VI subject)	2	(i) and (v)	Incorrect
2a (VR subject)	3	(ii) and (iii)	Correct
2b (VI subject)	3	(ii) and (iv)	Correct

Note. Correct instructions were designed to accurately inform subjects about the actual reinforcement contingencies. Incorrect instructions were designed to produce low response rates regardless of the schedule contingencies.

Subjects returned to participate in Sessions 2 and 3 on consecutive days. During these sessions, Computer A provided a VR 30 schedule and Computer B provided a yoked VI schedule for the entire 40-min session. Subjects also received additional instructions that were either correct (i.e., accurately specifying the reinforcement contingencies) or incorrect (designed to produce low response rates even though higher rates would increase the reinforcement rate under the actual contingencies). During Sessions 2 and 3, subjects in Subgroups 1a and 1b were given correct instructions and incorrect instructions, respectively. Subjects in Subgroups 2a and 2b received their instructions in the opposite order.

The additional instructions were written on cards and taped to the table in place of the initial minimal instructions. The new instructions consisted of various combinations of the paragraphs below. (The specific sequences of paragraphs presented to subjects in Sessions 2 and 3 are outlined in Table 1.)

> (i) Now I will tell you more about the game to help you improve your performance.
> (ii) The situation has now been slightly changed.
> (iii) The game is designed to pay you based on how many times your spaceship fires. On the *average*, it will require you to fire 30 times before you can destroy the enemy spaceship with a direct hit (in the center of the enemy spaceship). You may only need to fire 1 time

to be paid, or maybe 60 times, but, on the *average*, you will need to fire 30 times before the next direct hit destroys the enemy spaceship. Good luck.

(iv) The game is designed to pay you according to a time pattern. A direct hit (in the center of the enemy spaceship) will destroy the enemy spaceship only after a randomly selected period of time has passed. For example, you may have to wait 2, 10, or maybe 20 seconds before your next direct hit will destroy the enemy spaceship. You must guess when the time period has passed and the enemy spaceship is able to be destroyed with your next direct hit. Good luck.

(v) The game is designed to pay you according to a time pattern. Every time you win, the game will require you to wait 20 seconds before it will let you win again. If you fire before the 20 second waiting period is up, the game's clock will reset itself and you will have to wait another 20 seconds. Good luck.

The subjects were interviewed concerning their response strategies and briefed concerning the experiment following completion of Session 3.

Results

A cumulative response graph was produced for each subject in each of the three conditions by plotting the cumulative number of responses in successive 30-s intervals across each 40-min session. This resulted in three cumulative response profiles per subject: baseline, correct instructions, and incorrect instructions. The six cumulative response profiles of the 2 subjects in each team were depicted on the same set of axes, showing the differences in response patterns of VR and yoked VI subjects across the baseline, correct instructions, and incorrect instructions conditions.

Figure 9 presents the response profiles for the six teams in Experiment 2. Teams 1, 3, and 5 were in Group 1, which presented VR and yoked VI subjects with correct and then incorrect instructions following the baseline session. Teams 2, 4, and 6 were in Group 2, which received instructions in the opposite order following the baseline session. For all six teams in both groups, there was a large, positive difference in response totals between VR and yoked VI subjects at the end of the baseline sessions. Because the consummatory response, shaping, and lean instructions were included in these sessions, the results essentially replicated those of Condition CSL in Experiment 1.

For teams in Group 1 (left column of Figure 9), VR subjects showed an increase in response rate from baseline to the correct instructions condition (Session 2), whereas yoked VI subjects showed a decrease or, in the case of Team 1, a very slight increase from one condition to the next. In the incorrect instructions condition (Session 3), yoked VI subjects often showed a further decrease in response rate from baseline, whereas the VR subjects showed a slight to moderate change from baseline, always less than what was produced by the condition in Session 2.

With Teams 2 and 4 in Group 2 (right column of Figure 9), both VR and yoked VI subjects varied only slightly in response rate between the baseline and the correct instructions condition. Both VR and yoked VI groups of subjects also displayed decreases in response rate with incorrect instructions relative to the baseline condition, but the decrease was more marked for VI subjects.

A possible confounding effect occurred with Team 6 in Group 2. Early in Session 3 (the condition in which correct instructions were used), the yoked VI subject of the team complained that his joystick was working improperly. An experimenter entered the room and tested the joystick by firing at the target several times in rapid succession. Satisfied that the joystick was working properly, he left the room. No verbal exchange occurred between the subject and experimenter. However, the subject immediately began firing rapidly at the target and continued the rapid pace for the remainder of the session. This differed from the very slow pace he had maintained during Session 2 when incorrect instructions were used. It appears that the experimenter's intervention was enough to induce the subject to drastically increase his response rate.

Discussion

The results provide a picture of adult human sensitivity to reinforcement contingencies in the context of instructions. In both groups, instructions affected both VR and yoked VI subjects' responding in the two experimental conditions, although the effects

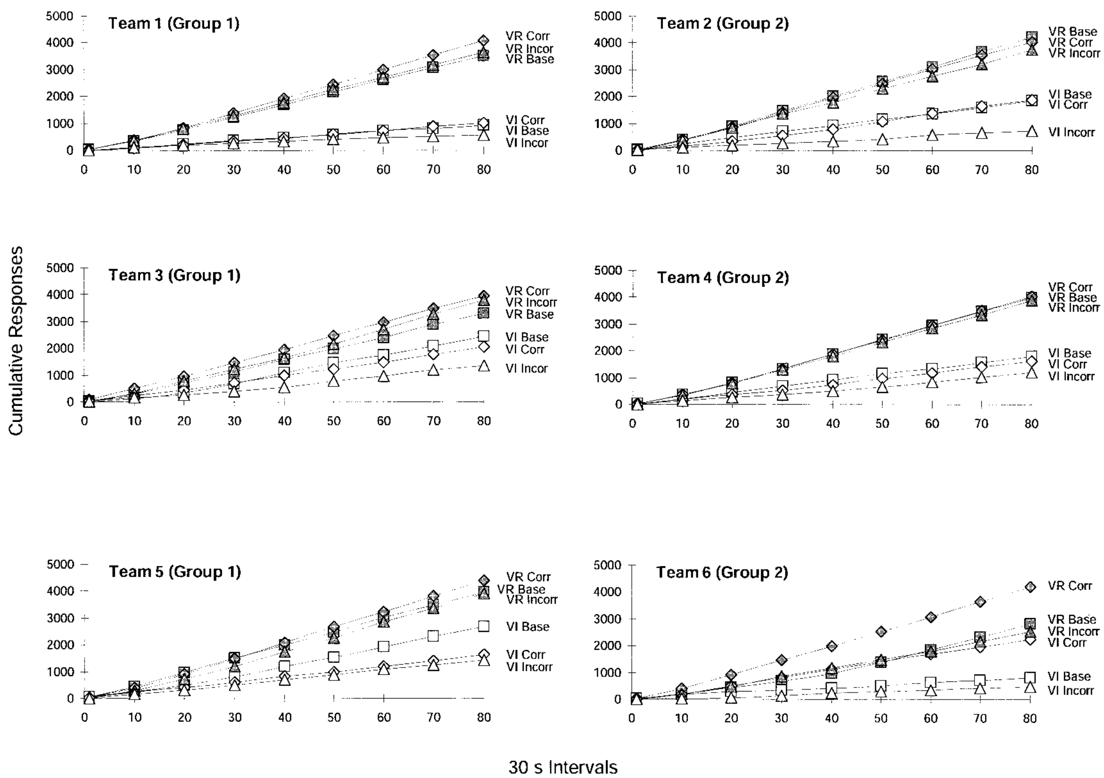

Fig. 9. Cumulative response graphs for VR and yoked VI subjects in the baseline and experimental conditions of Experiment 2. Graphs show cumulative numbers of joystick responses of VR (shaded points) and yoked VI (open points) subjects in successive 30-s intervals across three 40-min sessions. This figure allows comparison of VR and yoked VI subject response patterns in baseline sessions (squares) and subsequent experimental sessions in which correct (diamonds) or incorrect (triangles) instructions were used. Subjects in Group 1 were given correct followed by incorrect instructions in the experimental conditions; subjects in Group 2 received instructions in the opposite order.

were not identical. In both groups, responding on the yoked VI schedule was affected more by incorrect instructions than was responding on the VR schedule. Because the incorrect instructions were designed to induce low rates of responding, the changes in yoked VI responding in the incorrect instructions condition were always in the negative direction. Although VR response rates in the incorrect instructions sessions decreased moderately in Group 2, in Group 1 they increased slightly. These effects suggest the greater resistance of VR contingencies to instructional control.

The order of instructions had an effect as well. For Group 1, correct instructions caused an increase in response rate in the VR subjects and a decrease in the yoked VI subjects relative to the baseline condition. Such performances might reasonably be expected from subjects who have been informed in more detail concerning the contingencies. However, in Group 2, performance in the baseline condition and the correct instructions condition was similar for both VR and yoked VI subjects (Teams 2 and 4). Exposure to incorrect instructions during Session 2 apparently diminished the effect of correct instructions in Session 3. When interviewed, most subjects in Group 2 claimed that they simply ignored the instructions in Session 3 because following the instructions in Session 2 had led to lower winnings.

The large increase in responding during Session 3 by the VR subject on Team 6 remains unaccounted for. However, the similar jump in responding by the yoked VI subject can be considered an instance of imitation following the experimenter's silent but salient intervention.

GENERAL DISCUSSION

The findings of Experiments 1 and 2 offer support for two assertions concerning adult human operant behavior, specifically, behavior maintained by contingencies of reinforcement. First, certain conditions must be in place for reinforcement contingencies to affect human responding in ways that are characteristically observed in nonhuman subjects. When those conditions include performance of a consummatory response, shaping, and minimal (lean) verbal instructions about the task, human subjects display strong sensitivity to actual contingencies, that is, their response patterns closely resemble those of nonhuman subjects. Deviation from these optimal conditions for schedule control does not necessarily mean that human performance becomes insensitive to the contingencies. However, when the optimal conditions are altered, subjects' responsiveness to contingencies varies with the type of alteration. Most notably, deviation from minimal instructions has a marked influence on human responsiveness to contingencies, but the specific influence of instructions appears to involve an interaction between the type of instructions and other contextual factors, particularly the conjoint presence or absence of a consummatory response and shaping.

Second, responding on VR and VI schedules does not seem to be equally affected by manipulations of the experimental context. Responding on VR schedules can usually be considered more independent of such changes, given the stability of VR responding across different contexts (relative to the variability observed in VI responding). It is also the case that responding on VR schedules is more resistant to instructional control than that on VI schedules. This greater independence of VR responding is possibly due to the stronger correlation between response rate and reinforcement rate that is inherent in VR compared to VI schedules (Mazur, 1998).

Still, it is possible that further variations on the factors investigated in this study, that is, different instruction types, shaping procedures, or types of consummatory responses, may affect sensitivity to reinforcement contingencies in ways different from those reported here. The same could be said of variations in other parameters of the context such as reinforcer quality, response type, the procedure for reinforcement delivery, session length, and so forth. What was considered optimal in the present study may be superseded by new combinations of factors that are implemented in future research.

REFERENCES

Ayllon, T., & Azrin, N. H. (1964). Reinforcement and instructions with mental patients. *Journal of the Experimental Analysis of Behavior, 7,* 327–331.

Baron, A., & Galizio, M. (1983). Instructional control of human operant behavior. *The Psychological Record, 33,* 495–520.

Baron, A., Kaufman, A., & Stauber, K. A. (1969). Effects of instructions and reinforcement feedback on human operant behavior maintained by fixed-interval reinforcement. *Journal of the Experimental Analysis of Behavior, 12,* 701–712.

Baron, A., & Perone, M. (1982). The place of the human subject in the operant laboratory. *The Behavior Analyst, 5,* 143–158.

Bentall, R. P., & Lowe, C. F. (1987). The role of verbal behavior in human learning: III. Instructional effects in children. *Journal of the Experimental Analysis of Behavior, 47,* 177–180.

Bentall, R. P., Lowe, C. F., & Beasty, A. (1983). Does language produce behavioural rigidity in humans? *Behaviour Analysis Letters, 3,* 251–252.

Brewer, W. F. (1974). There is no convincing evidence for operant or classical conditioning in adult humans. In W. B. Weiner & D. S. Palermo (Eds.), *Cognition and the symbolic processes.* Hillsdale, NJ: Erlbaum.

Buskist, W. F., Bennett, R. H., & Miller, H. L., Jr. (1981). Effects of instructional constraints on human fixed-interval performance. *Journal of the Experimental Analysis of Behavior, 35,* 217–225.

Catania, A. C. (1979). *Learning.* Englewood Cliffs, NJ: Prentice Hall.

Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement.* New York: Appleton-Century-Crofts.

Herrnstein, R. J. (1970). On the law of effect. *Journal of the Experimental Analysis of Behavior, 13,* 243–266.

Kaufman, A., Baron, A., & Kopp, R. E. (1966). Some effects of instructions on human operant behavior. *Psychonomic Monograph Supplements, 1,* 243–250.

Killeen, P. (1967). Reinforcement frequency and contingency as factors in fixed-ratio behavior. *Journal of the Experimental Analysis of Behavior, 12,* 391–395.

Lattal, K. A. (1974). Combinations of response-reinforcer dependence and independence. *Journal of the Experimental Analysis of Behavior, 22,* 357–362.

Lippman, L. G., & Meyer, M. E. (1967). Fixed interval performance as related to instructions and to subjects' verbalizations of the contingency. *Psychonomic Science, 8,* 135–136.

Lowe, C. F. (1979). Determinants of human behavior. In M. D. Zeiler & P. Harzem (Eds.), *Reinforcement and the organization of behavior* (Vol. 1). New York: Wiley.

Lowe, C. F., Beasty, A., & Bentall, R. P. (1983). The role of verbal behavior in human learning: Infant performances on fixed-interval schedules. *Journal of the Experimental Analysis of Behavior, 39,* 157–164.

Lowe, C. F., Harzem, P., & Hughes, S. (1978). Determinants of operant behaviour in humans: Some differences from animals. *Quarterly Journal of Experimental Psychology, 30,* 373–386.

Matthews, B. A., Shimoff, E., Catania, A. C., & Sagvolden, T. (1977). Uninstructed human responding: Sensitivity to ratio and interval contingencies. *Journal of the Experimental Analysis of Behavior, 27,* 453–467.

Mazur, J. E. (1998). *Learning and behavior* (4th ed.). Englewood Cliffs, NJ: Prentice Hall.

Schmitt, D. R. (1974). Effects of reinforcement rate and reinforcer magnitude on choice behavior of humans. *Journal of the Experimental Analysis of Behavior, 21,* 409–419.

Streifel, S. (1972). Timeout and concurrent fixed-ratio schedules with human subjects. *Journal of the Experimental Analysis of Behavior, 17,* 213–219.

Weiner, H. (1970). Instructional control of human operant responding during extinction following fixed-ratio conditioning. *Journal of the Experimental Analysis of Behavior, 13,* 391–394.

Zuriff, G. E. (1970). A comparison of variable-ratio and variable-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior, 13,* 369–374.

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